



Overview of IFE Chamber and Target Technologies in the U.S. *

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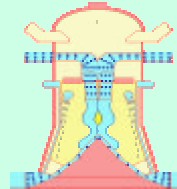
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Abstract

The U.S. Department of Energy, Office of Fusion Energy Science (OFES) formed the Virtual Laboratory for Technology (VLT) to develop the technologies needed to support near term fusion experiments and to provide the basis for future magnetic and inertial fusion energy power plants. The scope of the inertial fusion energy (IFE) element of the VLT includes the fusion chamber, driver/chamber interface, target fabrication and injection, and safety and environmental assessment for IFE. Lawrence Livermore National Laboratory, in conjunction with other laboratories, universities and industry, has written a five-year R&D plan to address the critical issues in these areas in a coordinated manner. This paper provides an overview of the U.S. research activities addressing these critical issues.

Introduction

- Previous IFE power plant conceptual design studies identified many different chamber / driver / target combinations and the critical technical issues associated with them.
- Current R&D in the U.S. is primarily focused on two options:
 - The renewable, thick-liquid-wall chamber (HYLIFE-II) with a heavy-ion driver and indirect-drive targets
 - The gas-protected, dry-wall chamber (Sombbrero) with a laser driver (KrF or diode-pumped, solid-state) and direct-drive targets
- Top level critical issues are summarized and examples of current R&D are given here.



HYLIFE-II

Different scales
First wall radius:
HYLIFE = 3.5 m
SOMBREIRO = 6.5 m



SOMBREIRO

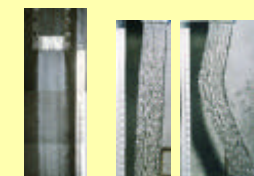
Key issues for thick-liquid-wall chambers with heavy-ion-driven, indirect-drive targets

- **Chamber Clearing:** Can the liquid pocket and beam port protection jets be made repetitively without interfering with beams? Will vapor condensation, droplet clearing and flow recovery occur fast enough to allow pulse rates of ~ 6 Hz?
- **Final Focus Magnet Interface:** Can superconducting final focusing magnet arrays be designed consistent with chamber and target solid angle limits for the required number of beams, standoff distance to the target, magnet dimensions and neutron shielding thickness?
- **Target Fabrication and Injection:** Can hohlraum targets with internally mounted cryogenic fuel capsules be mass produced with the required target precision at a cost less than ~ 0.3 U.S. dollars each? Can these targets withstand the acceleration forces of injection? Can they be injected, tracked and shot with sufficient accuracy and reliability?
- **Safety and Environment:** Can a level of safety be achieved so that a public evacuation plan is not required (< 10 mSv (1 rem) site boundary dose) for credible accident scenarios? Can radioactive hohlraum materials be recovered from flibe and recycled in new targets?

Key issues for gas-protected, dry-wall chambers with laser-driven, direct-drive targets

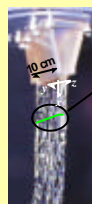
- **Chamber Lifetime:** Can the first wall be protected from x-ray and debris damage? Can first wall and blanket structures tolerate the effects of neutron damage for an acceptably long time and be designed for economical replacement? Can graphite channels last long enough against erosion due to Li₂O granule abrasion?
- **Final Optics Protection:** Can final optics be adequately protected from laser, neutron, x-ray and debris damage sufficient to survive for more than one year before replacement? Will final optics have sufficient mechanical stability under pulsed operation to maintain the required pointing accuracy for target tracking?
- **Target Fabrication and Injection:** Can direct-drive targets be manufactured at low cost and survive injection into a hot chamber? Can injection, tracking and triggering be sufficiently predictable with turbulence in the chamber gas?
- **Safety and Environment:** Can a level of safety be achieved so that a public evacuation plan is not required needed for credible accident scenarios? Can replaced chamber materials be recycled to minimize annual waste volumes?

Chamber Experiments and Analyses



No flow conditioning
Bad: Breaks up
Stationary
Better: No droplets
Oscillating
Better: No droplets
UCB Stationary Jets (1.6 cm x 8.0 cm, view from flat side, Re = 160,000, We = 29,000)

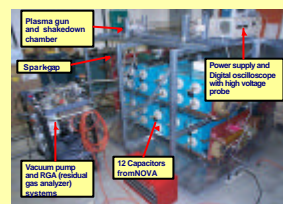
Oscillating liquid jet experiments are being carried out at UC Berkeley.



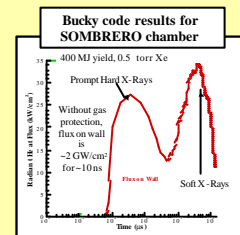
Free surface visualization:
Laser-induced fluorescence of a water jet



Special techniques are used to characterize surface ripple at Georgia Institute of Technology



A plasma gun will be used for flibe vaporization and condensation experiments at UCLA.



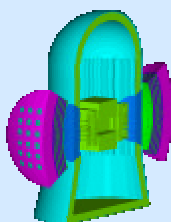
Chamber dynamics modeling is being conducted at the University of Wisconsin.

Driver / Chamber Interface

Laser Specs:
2 J
8 ns
Fundamental:
1.06 μm
Harmonics:
0.532 μm
0.355 μm
0.266 μm

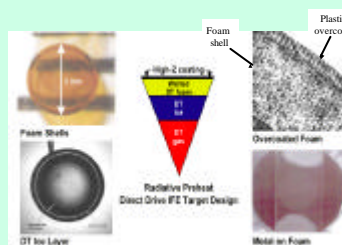


Laser damage test facility at UC San Diego is being used to investigate final optics damage and protection schemes.



At LLNL and the University of Wisconsin, 3D neutronics models are being used for shielding analyses of laser optics and final focus magnets.

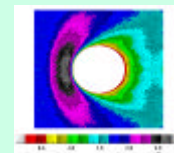
Target Fabrication and Injection



Target fabrication work at LANL, LLNL and General Atomics is focused on material and process development.



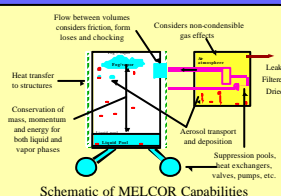
Preliminary target injection experiments met the accuracy requirements for indirect-drive (± 0.2 mm). A more capable injector is being built at General Atomics.



Target heating during injection into Sombbrero chamber (1760 K back-ground gas) is being simulated. Methods of reducing heating are being investigated.

Safety and Environment

LLNL, INEEL and the University of Wisconsin are collaborating on safety analyses for IFE power plants. Preliminary cases for HYLIFE-II and Sombbrero have been completed.



Summary

- The IFE technology program covers chambers, driver/chamber interface, target fabrication and injection and safety and environmental assessments.
- Key issues have been identified for both heavy ion and laser driven IFE power plants.
- Experiments, analyses and modeling are being carried out at national laboratories, universities and industry to resolve these issues.